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FLIGHT TRIAL OF THE AIRCRAFT FATIGUE DATA ANALYSIS SYSTEM (AFDA--ETC(U)
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FLIGHT TRIAL OF THE AIRCRAFT FATIGUE DATA ANALYSIS SYSTEM (AFDAS) MK 2 PROTOTYPE

by

P. J. HOWARD

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SUMMARY

A prototype version of the Aircraft Fatigue Data Analysis System (AFDAS) has been evaluated in flight trials by a comparison with continuously recorded data. Over a limited period of test the range-mean-pairs count of strain cycles was the same for both sets of data, and the gains calculated for the AFDAS are identical to those deduced from the continuous record.

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ABSTRACT

A prototype version of the Aircraft Fatigue Data Analysis System (AFDAS) has been evaluated in flight trials by comparison with continuously recorded data. Over a limited period of test the range-mean-pairs count of strain cycles was the same for both sets of data, and the gains calculated for the AFDAS are identical to those deduced from the continuous record.

CONTENTS

1. INTRODUCTION

An Airborne Fatigue Data Analysis System (AFDAS) developed by British Aerospace Australia Ltd. (B.Ae.A.) from an original concept proposed by the Aeronautical Research Laboratories (ARL) has been flight tested in a Mirage III-0 aircraft (A3-002). This note compares data obtained from AFDAS with similar data obtained from continuous time histories recorded digitally on magnetic tape using an ARL recording system (AFTRAS) during trials conducted between 6 September and 9 November 1979.

2. DESCRIPTION OF SYSTEMS

2.1 AFDAS

Both AFDAS and AFTRAS have been described.[1,2] The airborne component of AFDAS, the strain–range-pair counter (SRPC) detects turning points in strain (or other parameter); pairs peaks and troughs according to the range-mean-pairs algorithm[3] and stores the information in a 14×14 half-matrix. Eight input signals can normally be accepted, but in these trials only two strain guage amplifiers were available so that only two bridges could be interrogated. These were 21C on fin post (Fig. 1) and 18T on wing main spar (Fig. 2). The test of the instrument was broadened slightly by routing these signals to memory channels 0 and 2 (21C) and 1, 3 and 4 (18T). Channels 5–7 were unconnected and the internal offset was set offscale (Fig. 3). Signals in AFDAS are quantised at a series of levels, labelled 0–15, which are defined by bounding threshold strains. To ease discussion these thresholds are symbolised ${}_i\epsilon_j$, so that the strain separating level 3 from level 4, for an ascending signal is ${}_3\epsilon_4$. For the instrument ${}_4\epsilon_3 \simeq {}_3\epsilon_4$. All strain values $< {}_1\epsilon_0$ or $> {}_{14}\epsilon_{15}$ are stored in the appropriate outer level, so that an ill-chosen offset or gain will be characterised by many counts in one or both of these extreme levels. The SRPC was mounted in the instrumentation bay, and could be switched on or off from the cockpit. Readout was performed by a ground-based interrogator display and recording unit (IDRU) which transfers range pairs, pending (unpaired) turning points, terminal signal level and direction and documentary data to a tape cassette, which is later read into a computer.

Printouts from the computer formed one half of the primary data for the comparison. The values ${}_i\epsilon_j$ are calculated from known circuit parameters using the following relation

$$ {}_i\epsilon_j = \frac{4K({}_iV_j - V_k) \times 10^6}{G \times B \times V_r \times A} \text{ microstrain } (\mu\epsilon) $$

where K = lead resistance factor, 1·0117 = assumed for all gauges,

${}_iV_j$ = counter threshold voltage,

V_k = offset voltage; = 0 for 21C = 1·54 V for 18T,

G = gauge factor = 2·09,

B = bridge factor = 2·66

μ = Poisson's ratio = 0·33,

V_r = bridge reference voltage = 5 V,

A = amplifier gain: = 379 for 21C = 263·5 for 18T.

V_k and A are fixed by selection of precision resistors, which, in the interest of stability, are hard wired into the amplifier circuit. Values of ${}_iV_j$ are listed in Table 1, along with ${}_i\epsilon_j$ calculated by B.Ae.A. (column 1) and recalculated at ARL (column 2). Values in the two columns differ

because of slight differences (now resolved) in values of μ, K, and G used at the two establishments. ARL values are consistent with values used in a similar calculation for AFTRAS.

2.2 AFTRAS

This equipment is designed for versatility rather than as a long-term fixed installation. Data are generally recorded digitally in computer compatible format on ½" tape on 7" reels. Gain and offset are easily adjustable by potentiometer and so must be tracked by the instrumentation. This is effected by preceding each record by a sequence of calibration pulses which are obtained by bridging the active gauges by precision resistors and, for estimating offset, removing the bridge supply. The calibration (cal) signals are treated to the same processing as the data, and serve as scaling factors to transform the final output, in computer units, to engineering units of strain. Cal equivalents and other pertinent data for these trials and for an earlier calibration flight are listed in Table 2. The relation between strain and circuit values is obtained from the following expressions.[4]

The amplifier output, V_0, is related to the strain, ϵ, by

$$\frac{V_0}{V_r} = \frac{N\,G\,B}{4K}\,\epsilon \cdot \frac{R_g}{R_A} \cdot \frac{1}{1 + \dfrac{G\epsilon}{2}(1-\mu)\left(1 + \dfrac{R}{2R_n + R}\right)} \tag{1}$$

and the amplifier output for a calibration step, positive to negative, V_C, is given by

$$\frac{V_C}{V_r} = \frac{R_g}{R_A} \cdot \frac{(R + 2R_L)}{(2R_C + R)} \tag{2}$$

where V_r = bridge excitation voltage,

R = gauge resistance = 350 Ω,

R_L = lead resistance, ~2·05 Ω,

R_L = calibration resistor value,

R_g = amplifier first stage gain resistor = 47KΩ,

R_A = $R/2 + R_n$,

R_n = amplifier input resistance = 180 Ω,

G = gauge factor = 2·09,

B = bridge factor = $2(1+\mu)$ = 2·66,

$K = 1 + \dfrac{2R_L}{R}$, lead resistance factor,

$N = 1 - \dfrac{R}{4R_b}\left\{1 + \dfrac{(1-\mu)}{(1+\mu)\left(1 + \dfrac{R}{2R_b}\right)}\right\} \Big/ \left(1 + \dfrac{R}{2R_b}\right)$, bridge balance factor,

R_b = impedance of bridge balance network, ~11KΩ,

μ = Poisson's ratio = 0·33.

Taking the ratio of Equation (1) to Equation (2), substituting values and re-arranging

$$\epsilon = \frac{130{\cdot}47V_0}{(R_C + 175)V_C - 203{\cdot}56V_0}$$

or, since V_0 and V_C are proportional to the recorded digital signals, D_0 and D_C, and allowing for signal offset, D_0', we have

$$\epsilon = \frac{130{\cdot}47(D_0 - D_0')}{(R_C + 175)D_C - 203{\cdot}56(D_0 - D_0')}$$

AFTRAS was carried in the gun bay, so that the lead length was somewhat different to that used for AFDAS. However, this difference is estimated to affect the value of K by less than $0 \cdot 1\%$, and it has been ignored. AFTRAS could be switched on and off from the cockpit, independently of AFDAS. An event marker could also be operated from the cockpit. Instrumentation incompatibilities precluded the simultaneous feeding of AFDAS and AFTRAS from a single gauge bridge and so companion gauges 21T on the opposite side of the fin post to 21C (Fig. 1) and 1·4T on the opposite wing to 18T (Fig. 2) were connected to AFTRAS.

2.3 Strain Gauges

All strains were measured by four active arm (two tension, two Poisson) e.r.s.g. bridges formed from $350\,\Omega \pm 0 \cdot 3\%$. Micromeasurements type WK-13-K250BG-350 gauges with gauge factor $2 \cdot 09 \pm 0 \cdot 5\%$. Poisson's ratio, μ, was assumed to be $0 \cdot 33$ so that the bridge factor, $2(1+\mu), = 2 \cdot 66$.

The disposition of the gauge bridges allows separate excitation of the two pairs, pitching excites 1·4T and 18T, but not 21T or C whereas yawing or rolling excites the fin gauges without substantial stressing of the wings.

2.4 Calibration

Earlier data (flight 12, dated 22/9/78) were analysed to provide a means of estimating the AFDAS gauge output from the AFTRAS measured strain. For symmetric manoeuvres the regression of 18T upon 1·4T was linear and, omitting offset,

$$\epsilon_{18T} = 1 \cdot 031 \epsilon_{1.4T}.$$

The presence of roll during a manoeuvre caused considerable deviation (Fig. 4) because, being on opposite wings, gauges 1·4T and 18T were oppositely excited during roll accelerations.

The regression of 21C upon 21T was non-linear (Fig. 5). A quadratic approximation yielded, omitting offset,

$$\epsilon_{21C} = -1 \cdot 0273 \epsilon_{21T} - 0 \cdot 000192 \epsilon^2_{21T}.$$

The residual S.D. about this regression, estimated from the residual sum of squares, is $6 \cdot 5\mu\epsilon$, and the variance of the regression coefficients is negligible.

Variations in gauge output may have arisen in the year since the calibration flight, but experimental constraints have forced these to be ignored. During the analysis it was assumed that zero strain existed for the fin gauges in on-ground measurements, and for wing gauges at $N_Z = 0$. Although this necessary assumption cannot be justified by theory or experiment it is in reasonable accord with experience.

3. TRIALS AND ANALYSIS

3.1 Flight Profiles

Although dedicated flights were requested, only three short segments, in flights 30, 44 and 50 (Table 3), were available for analysis. These were obtained by switching on AFDAS and eventing AFTRAS, nearly simultaneously, in level flights, performing a nominated set of manoeuvres to excite wings (flight 30) or fin (flights 44 and 50) (Fig. 6) and switching off/eventing as for the start of the record.

The AFDAS segment of flight 30 consisted of a series of pitching manoeuvres, substantially roll-free at peak load, to the load sequence $N_Z = +1, -2 \cdot 1, +5 \cdot 7, -1 \cdot 9, +5 \cdot 9, -1 \cdot 7, +1 \cdot 5, +6 \cdot 3, +1$g, as measured by the cockpit 'g' meter. This sequence was designed to ensure that at least one, and possibly two, transition strains were defined by producing counts in three adjacent cells at each end of the range. Fin gauge 21T was not recorded on AFTRAS. Values for altitude and airspeed for this segment were variable, average values were 400 kt, 14,000 ft.

The AFDAS segments for flights 44 and 50 consisted of rolls to left and right alternately, at about 200°/sec, repeated three times, each roll being separated by a short segment of level flight. Flight was at 400 kt IAS and 6000 ft altitude. Output from gauge 1·4T was recorded on AFTRAS, but all strain peaks were recorded at high roll rate.

Aircraft configuration varied between flights, resulting in differences in mass and mass distribution. These differences, detailed in Table 3, were unlikely to have affected fin strains, but may have influenced wing strains.

3.2 Data Analysis—Range-Mean-Pair Count

The turning points from AFTRAS records were transformed to engineering units and corrected to probable AFDAS gauge reading as described. The corrected strains (Table 4) were subjected to a range-mean-pair count, assuming the transition strains recalculated at ARL. The method of counting is illustrated in Figure 7.

In this figure the "pre-flight stack" represents the unpaired turning points obtained from the IDRU output from the preceding flight. Where range-pair counts arise from pairing these turning points they necessarily conform to the AFDAS count; and so are no help in the comparison with AFTRAS. The "turning points from flight record" are those turning points giving rise to useful range-pairs, and the "end stack" represents the unpaired turning points from the flights. The end stack and any unpaired turning points from the pre-flight stack will compare with end stack contents in the IDRU readout. The logic ensures that a turning point is always stored in stack level 0. A range-pair is counted when two adjacent turning points are preceded by one at a higher level and followed by one at a lower level or vice versa. The first five turning points in the sequence of Figure 7 are entries in the pre-flight stack and have not yet been consummated into range-pairs. The first turning point in the flight record consummates range-pair No. 1 (by returning to level 11, of which an event is stored in the stack), and the next two turning points, together with the excursion into level 5 and beyond, consummates range-pair No. 2. Return to level 0 consummates range-pairs 3 and 4 from the pre-flight stack.

The same number of range-mean-pairs were obtained by this process as were counted by AFDAS, but counts were sometimes assigned to adjacent cells in the count half-matrix (Fig. 8*a*–*e*).

3.3 Data Analysis—Estimate of Gain

The possibility that the experimentally determined strain transition values derived by AFTRAS differed from values calculated from circuit parameters was further investigated by listing AFDAS count levels against AFTRAS strains (Table 5). Pairs of values were then plotted and lines were drawn through the data to represent the overall gains for AFDAS.

For gauge 21C the gain was fixed within narrow limits (Fig. 9) and is close to the value calculated at ARL. The probable transition strains are listed in column 3, Table 1. Figure 10 shows the result of using these strain transition values to count range-mean-pairs for gauge 21C.

The position for gauge 18T is less fortunate. Due to a misunderstanding the AFDAS zero was improperly set so that all the strain troughs occurred in level 0. In consequence the only information from this source was that the threshold strain, ${}_1\epsilon_0$, was less negative than the smallest trough. Since all the peaks were in levels 11 and 12 no clear indication of slope was given. Although turning points at levels between 1 and 11 were present in flights 44 and 50, these were always accompanied by roll which, as has been stated, complicates the regression of 18T on 1·4T. Many of the data points were associated with overload on the roll channel. Since exact magnitudes were not available a more complex model would not help even if it could be constructed.

All of the data for gauge 18T has been plotted in Figure 11 which illustrates the difficulties in deriving a gain for this channel.

A set of experimental transition strains has been derived (Table 2, column 3) from Figure 11, and it has been used to obtain range-pair counts for all three flight segments (Fig. 12). Many anomalies in the distribution of counts remain.

It is planned to produce continuous recording equipment which can sample from the same gauge as AFDAS, and to operate the two systems together over a large number of flights. Many of the limitations of these trials will thereby be overcome.

3.4 Data Analysis—Comparison of Memory Channels

The range-pair counter was switched on for portions of 18 flights in addition to the dedicated segments already analysed. Counts recorded in the several memory channels fed from a single gauge showed only trivial differences (Fig. 13*a*,*b*) which could be explained by postulating small differences in signal level at the time of sampling.

4. CONCLUSION

A prototype version of the Aircraft Fatigue Data Analysis System (AFDAS) has been evaluated in flight trials by comparison with continuously recorded data. Over a limited period of test the range-mean-pairs count of strain cycles was the same for both sets of data, and the gains calculated for the AFDAS equal those deduced from the continuous record.

Two interesting observations, which might repay closer analysis, were the effect of roll on wing strains, and the non-linear connection between strains on opposite sides of the finpost. Reference to Table 1, which compares calculated and experimental transition strains, indicates that some small uncertainty exists in the determination of offset, amounting to 20 $\mu\epsilon$ and 78 $\mu\epsilon$ for gauges 21C and 18T respectively.

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2. Anderson, B. E., and Woodall, G.—Macchi MB326H Flight Trials (Stage 3). Instrumentation and Flight Profiles. ARL Structures Note 432, September 1976.

3. Fraser, R. C.—A One-pass Method for Counting Range-Mean-Pair Cycles for Fatigue Analysis. ARL Structures Note 454, June 1979.

4. Patterson, A. K.—ARL Note, in preparation.

TABLE 1

Transition Voltages and Strains at Fin and Wing Gauges

Transit		Volts $({}_iV_j)$	Strain ($\mu\epsilon$) at gauge					
			21C			18T		
from	to		(1)	(2)	(3)	(1)	(2)	(3)
0	1	−2·459	−999	−945	−925	−540	−508	−430
1	2	−2·107	−856	−809	−789	−340	−313	−234
2	3	−1·756	−713	−675	−653	−140	−119	−39
3	4	−1·403	−570	−539	−517	60	76	157
4	5	−1·056	−428	−406	−381	260	267	353
5	6	−0·684	−285	−263	−245	460	473	549
6	7	−0·332	−142	−128	−109	660	667	744
7	8	0·013	0·4	5	28	860	858	940
8	9	0·366	143	141	164	1060	1053	1135
9	10	0·718	286	276	300	1260	1248	1331
10	11	1·091	428	419	436	1460	1454	1527
11	12	1·438	571	552	572	1660	1645	1723
12	13	1·792	714	688	708	1860	1841	1918
13	14	2·145	857	824	844	2060	2036	2114
14	15	2·500	1000	960	980	2260	2232	2310

(1) Values provided by B.Ae.A.
(2) Values re-calculated at ARL.
(3) Probable threshold strains from flight trials.

TABLE 2

Calibration Data for AFTRAS

Flight No.	Channel	Gauge No.	Amp. No.	Cal R_C resist. ($K\,\Omega$)	Strain equiv-alent	$D_C/2$ cal step	D_0' strain (zero)
12	18	21C	30	38·860	NOT USED	1636·9	2032
	19	21T	25	38·884		1623·7	2038
	24	1·4T	46	38·838		1527·0	2265
	26	18T	48	38·760		1477·6	1856
30	26	1·4T	29	38·871		821·5	1944
44 & 50	26	1·4T	24	38·871		821·3	1944
	27	21T	30	38·860		820·4	1820

TABLE 3
Aircraft Configuration and Manoeuvres Performed in AFDAS Flight Segments

Flight No.	Aircraft configuration	Manoeuvres recorded
30 (flown 12/10/79)	Supersonic tanks; 2× sidewinders and rails; all-up weight (AUW), 22,693 lbs at take off; Fuel at start, 798 gal; SG, 8·02 lb/gal. * Fuel at mid-point of AFDAS segment, 250 gals; AUW, 18,244 lbs; IAS variable around 400 Kt; altitude variable around 14,000 ft.	pitch up–pitch down −2·1g, +5·7g, −1·9g, +5·9g, −1·7g, +6·1g, −1·5g, +6·3g at cockpit
44 (flown 1/11/79)	2× sidewinders and rails; matra and pylon; AUW, 20,991 lbs at TO; fuel at TO, 562 gals. * Fuel at mid-point of AFDAS segment, 190 gals; AUW, 18,200 lbs; IAS, 400 Kt; altitude, 6000 ft.	3 off left and right rolls at 200°/sec
50 (flown 9/11/79)	Supersonic tanks; 2× sidewinders and rails; matra and pylon; AUW at TO, 23,019 lbs; fuel at TO, 775 gals. * Fuel at mid-point of AFDAS segment, 80 gals; AUW, 174W lbs; IAS, 400 Kt; Altitude, 6000 ft.	As 44
General	AFDAS switched on and off at 1g. AFTRAS evented at switching.	

* Fuel remaining probably underestimated; fuel flow sensor to be recalibrated.

TABLE 4A

Sequence of Strain Turning Points for Three Flight Segments
Measured on AFTRAS at gauge 1·4T and corrected to AFDAS strains at gauge 18T

Flight	30				44				50			
Gauge	1·4T			18T	1·4T			18T	1·4T			18T
T.P. No.	Time*	C.U.†	Strain‡	Strain	Time	C.U.	Strain	Strain	Time	C.U.	Strain	Strain
1	2698	1564	−771·9	−795·8	1489	2320	765·8	789·5	2259	2156	431·2	444·6
2	2739	2695	1531·0	1578·5	1491	2141	401·0	413·4	2271	2362	850·8	877·2
3	2758	1659	−579·1	−597·1	1494	2509	1151·4	1187·1	2273	2105	327·5	337·6
4	2806	2726	1594·3	1643·8	1495	2084	284·9	293·8	2276	2559	1252·6	1291·5
5	2836	1679	−538·5	−555·2	1500	2418	965·7	995·6	2277	2106	329·5	339·7
6	2883	2731	1604·6	1654·3	1501	2150	419·3	432·3	2282	2502	1136·3	1171·6
7	2920	1716	−463·4	−477·7	1506	2605	1347·4	1389·2	2284	2002	117·9	121·6
8	2980	2765	1674·1	1726·0	1507	2032	179·1	184·6	2285	2311	746·9	770·1
9					1513	2464	1059·5	1092·4	2285	2159	437·4	450·9
10					1514	2101	319·5	329·4	2287	2586	1307·7	1348·3
11					1519	2592	1320·9	1361·9	2288	2148	415·0	427·8
12					1520	2052	219·8	226·6	2295	2486	1103·7	1137·9
13					1523	2232	586·4	604·6	2297	2016	146·4	150·9
14									2298	2286	696·0	717·6
15									2298	2123	364·1	385·4
16									2300	2578	1291·4	1331·5

* Time in half-seconds since take-off.
† Computer units of strain from arbitary zero.
‡ Engineering strain, mean-strain units, assuming zero strain at zero load factor.

TABLE 4B

As Table 4A, but for AFTRAS gauge 21T and AFDAS gauge 21C

Flight Gauge T.P. No.	44				50			
	21T			21C Strain	21T			21C Strain
	Time	C.U.	Strain		Time	C.U.	Strain	
1	1487	1521	−608·5	554·0	2270	1452	−748·8	661·5
2	1489	1937	238·4	−255·8	2274	2478	1343·2	−1726·4
3	1490	1856	73·3	−76·4	2277	1499	−653·2	589·1
4	1493	2414	1212·3	−1527·7	2278	1940	244·5	−262·7
5	1495	1512	−626·8	568·4	2281	1031	−1603·2	1153·2
6	1496	1930	224·2	−239·9	2283	2165	703·6	−817·8
7	1499	1179	−1303·1	1012·5	2284	1928	220·1	−235·4
8	1501	2083	536·2	−606·1	2286	2541	1472·1	−1928·5
9	1502	1841	42·8	−44·3	2288	1372	−911·3	776·6
10	1505	2600	1592·8	−2123·7	2289	1970	305·7	−332·0
11	1506	1363	−929·6	789·0	2294	1120	−1422·8	1072·7
12	1507	1982	330·2	−360·1	2296	2201	777·1	−914·3
13	1512	1111	−1441·0	1081·4	2297	1932	228·2	−244·5
14	1514	2117	605·6	−692·5	2299	2489	1365·7	−1761·2
15	1515	1720	−203·6	201·2	2301	1415	−823·9	716·0
16	1518	2646	1687·0	−2279·8	2302	2012	391·4	−431·5
17	1520	1358	−939·7	795·7	2304	1764	−114·1	114·7
18	1521	1985	336·3	−367·2	2306	1873	108·0	−113·2
19					2307	1789	−63·1	64·1
20					2309	1891	144·7	−152·6
21					2310	1756	−130·3	130·6
22					2311	1872	105·9	−111·0
23					2312	1761	−120·2	120·7
24					2313	1895	152·8	−161·5

TABLE 5

Corrected Measured Strain
With probable AFDAS level

Gauge	18T						21C			
Flight	30		44		50		44		50	
T.P. No.	$\mu\epsilon$	Level	$\mu\epsilon$	Level	$\mu\epsilon$	Level	$\mu\epsilon$	Level	$\mu\epsilon$	Level
1	−796	0	185	3	122	4	−2280	0	−1929	0
2	−597	0	227	3	151	4	−2124	0	−1761	0
3	−555	0	294	4	340	5	−1528	0	−1726	0
4	−478	0	329	5	428	5	−693	2	−914	1
5	1579	11	432	5	1138	8	−606	3	−818	1
6	1644	11	605	6	1172	9	−367	5	−432	4
7	1654	11	996	8	1292	9	−360	5	−332	5
8	1726	12	1092	8	1332	9	−256	5	−263	5
9			1187	9	1348	9	−240	6	−245	5
10			1362	10			−76	7	−235	5
11			1389	10			−44	7	−162	6
12							201	9	−153	6
13							554	11	−113	6
14							568	11	−111	6
15							789	13	64	8
16							796	13	115	8
17							1013	15	121	8
18							1081	15	131	8
19									589	12
20									662	12
21									716	13
22									777	13
23									1072	15
24									1153	15

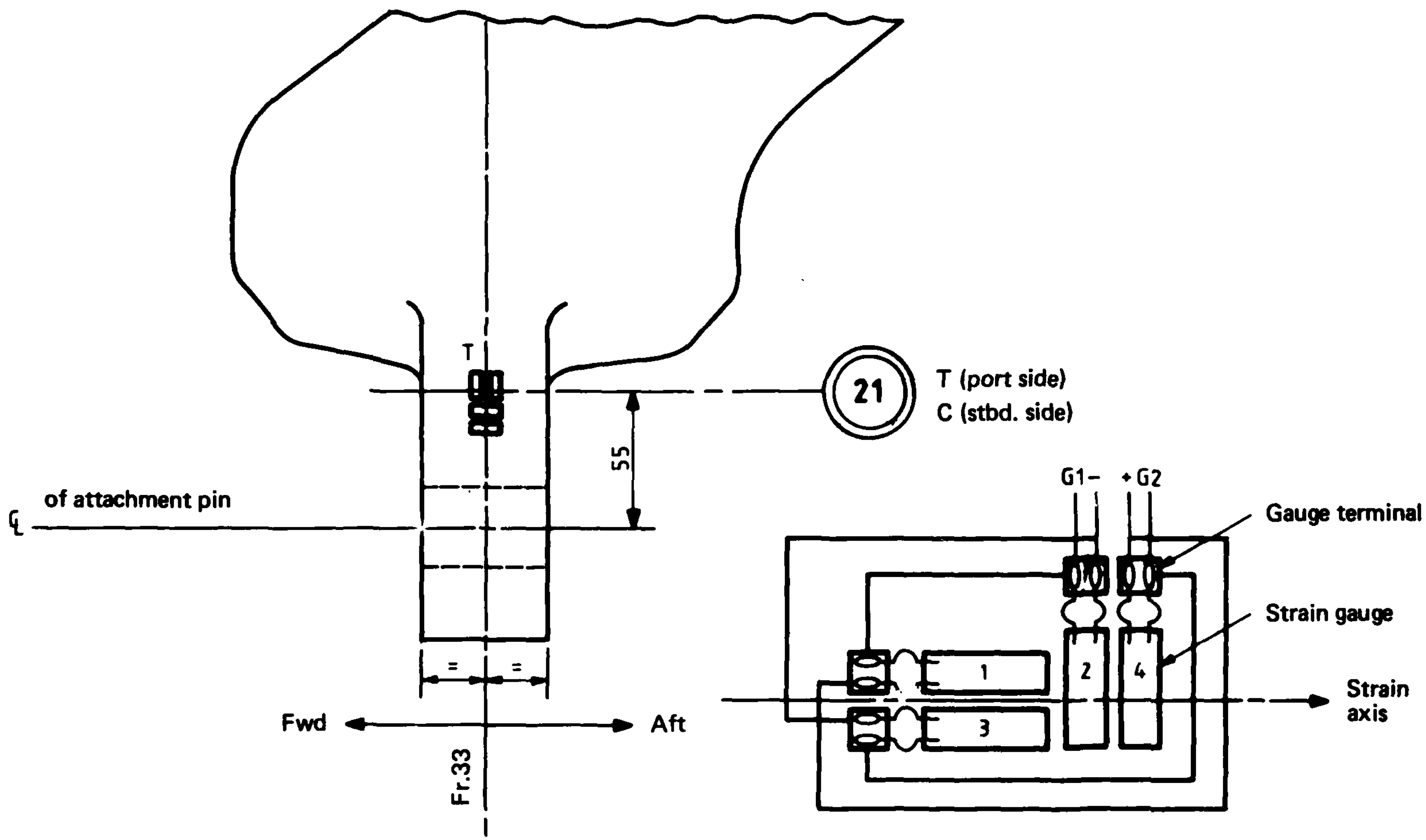


FIG 1 FIN POST GAUGES 21T AND 21C

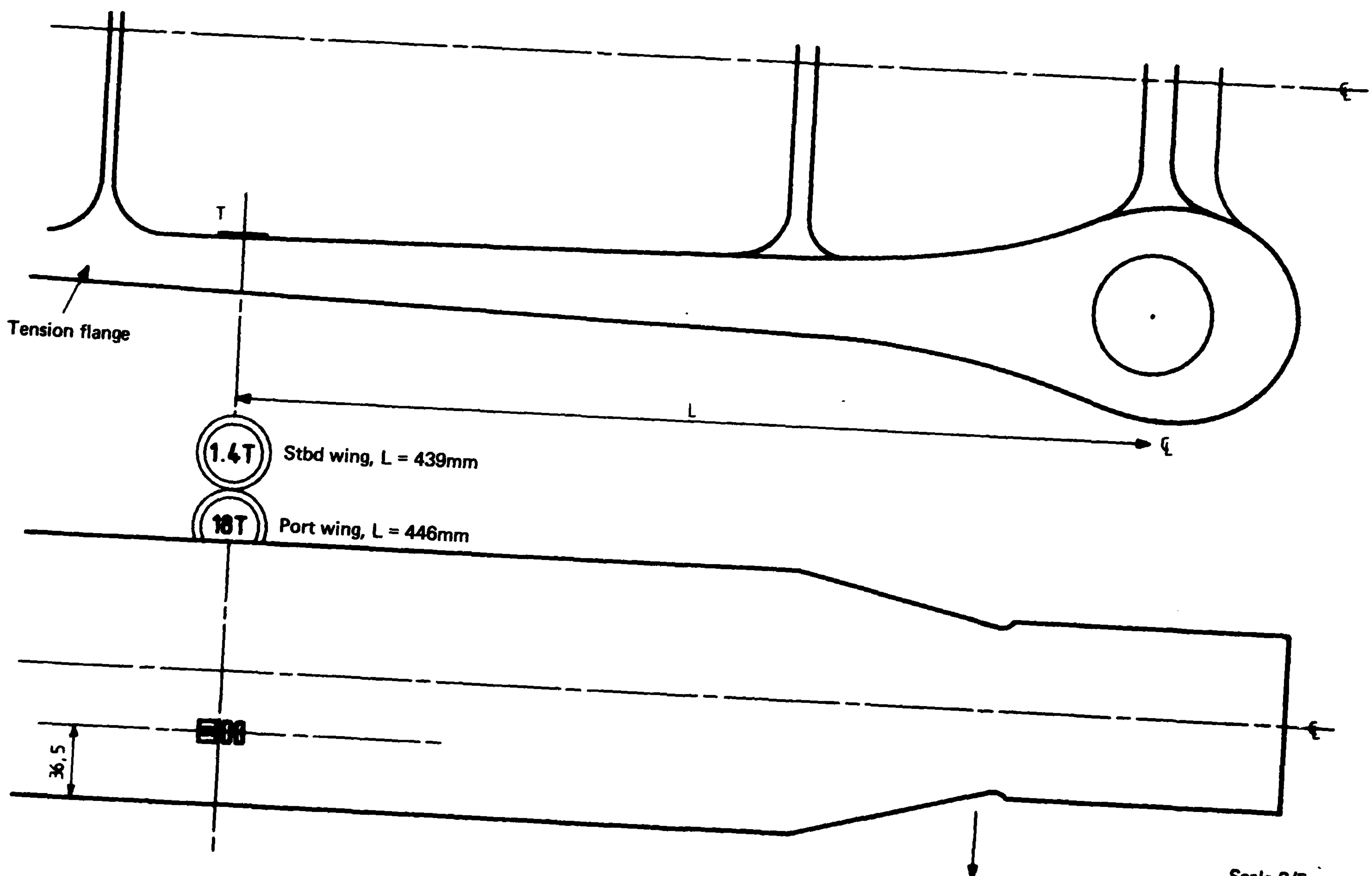


FIG 2 WING MAIN SPAR GAUGES 1.4T AND 18T

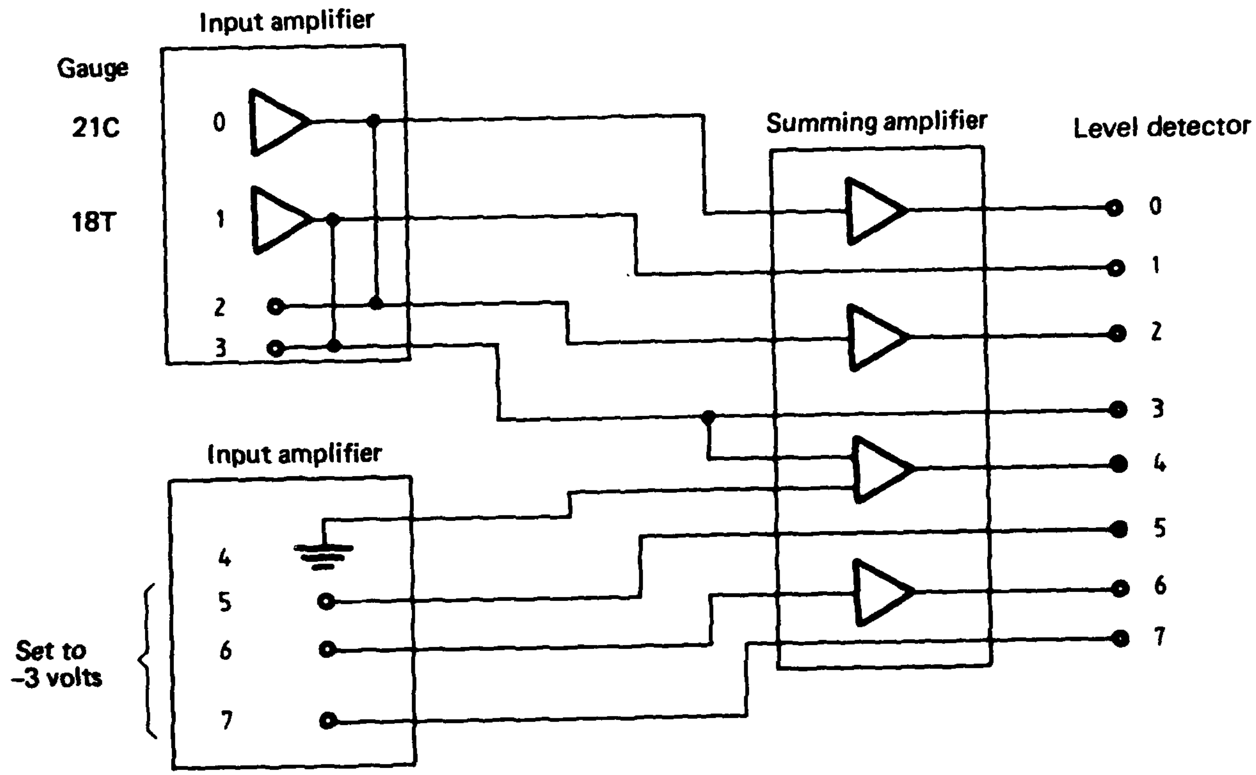


FIG 3 AFDAS INPUT SIGNAL CONFIGURATION

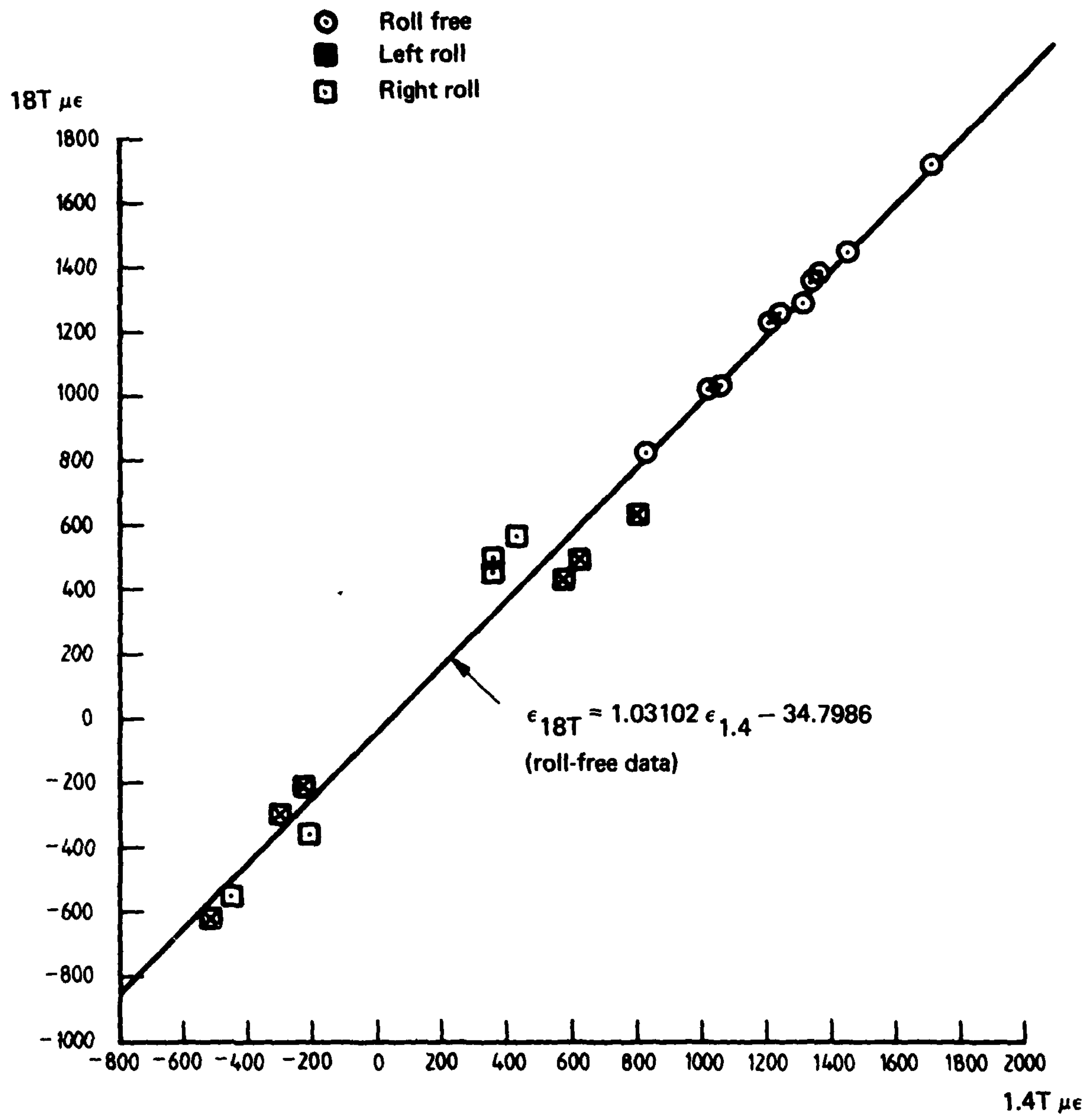


FIG 4 CORRELATION BETWEEN STRAINS MEASURED ON GAUGES 1.4T AND 18T, FLIGHT 12.

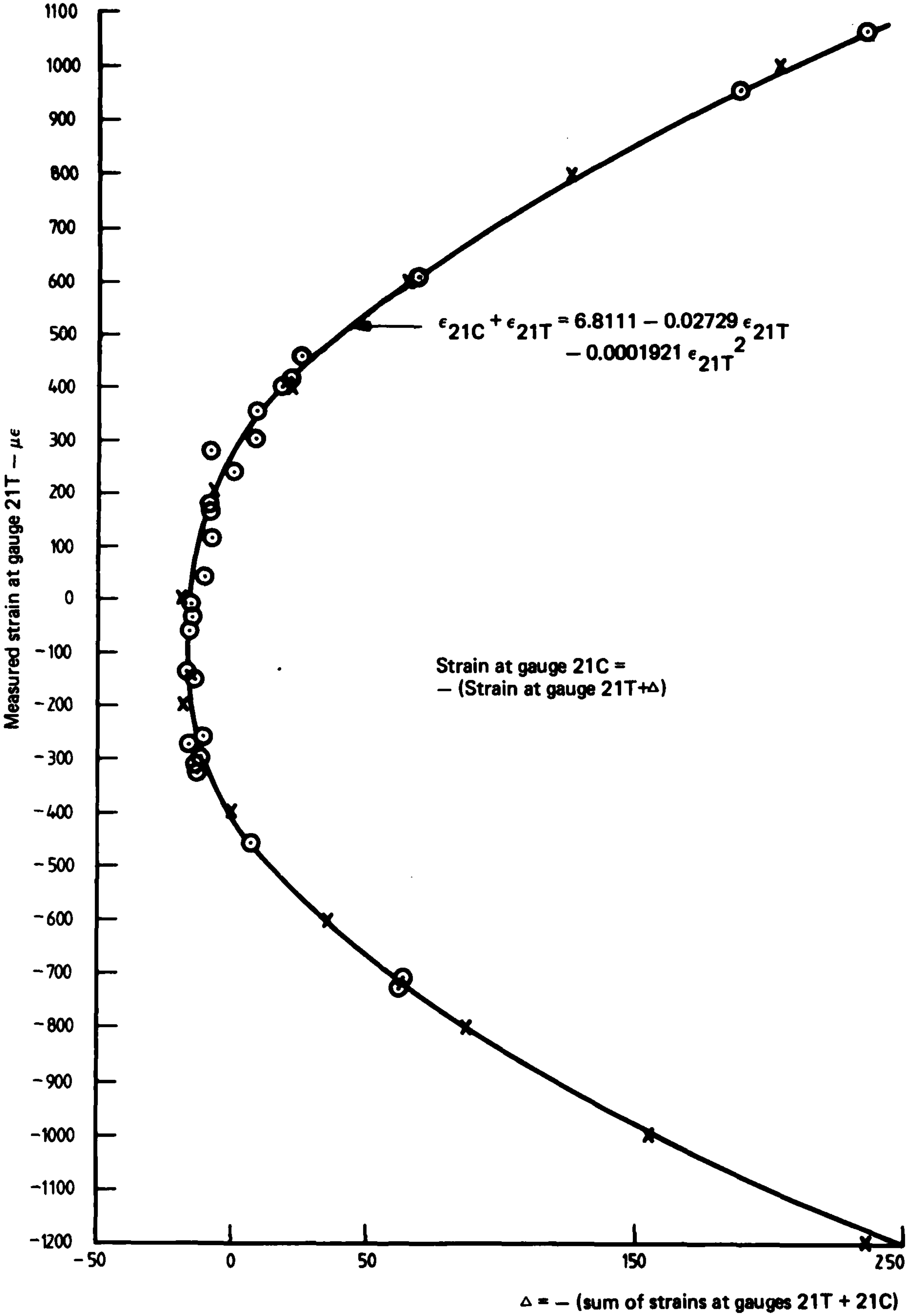


FIG 5 CORRECTION CURVE FOR ESTIMATING STRAIN AT GAUGE 21C FROM MEASURED STRAIN AT 21T

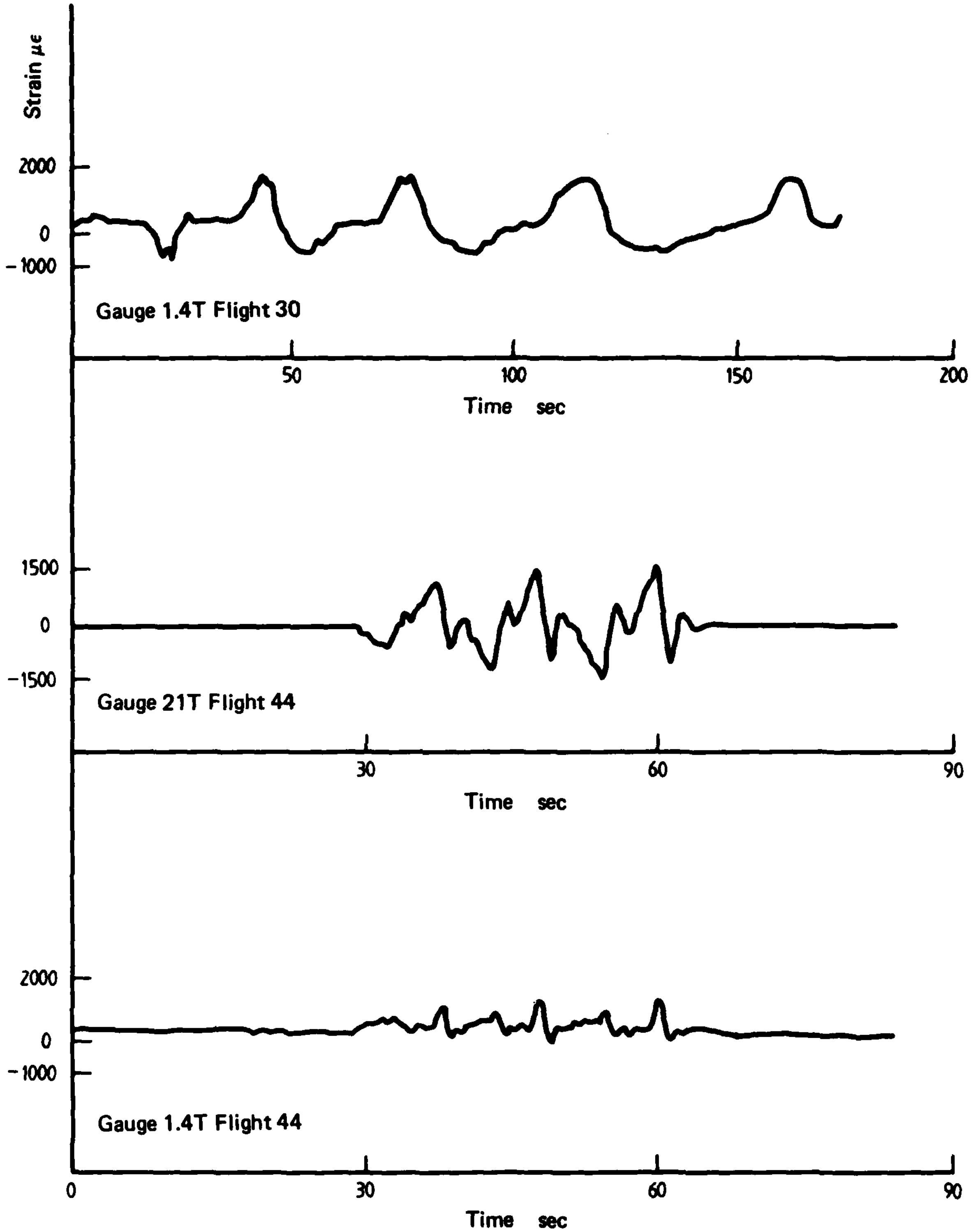
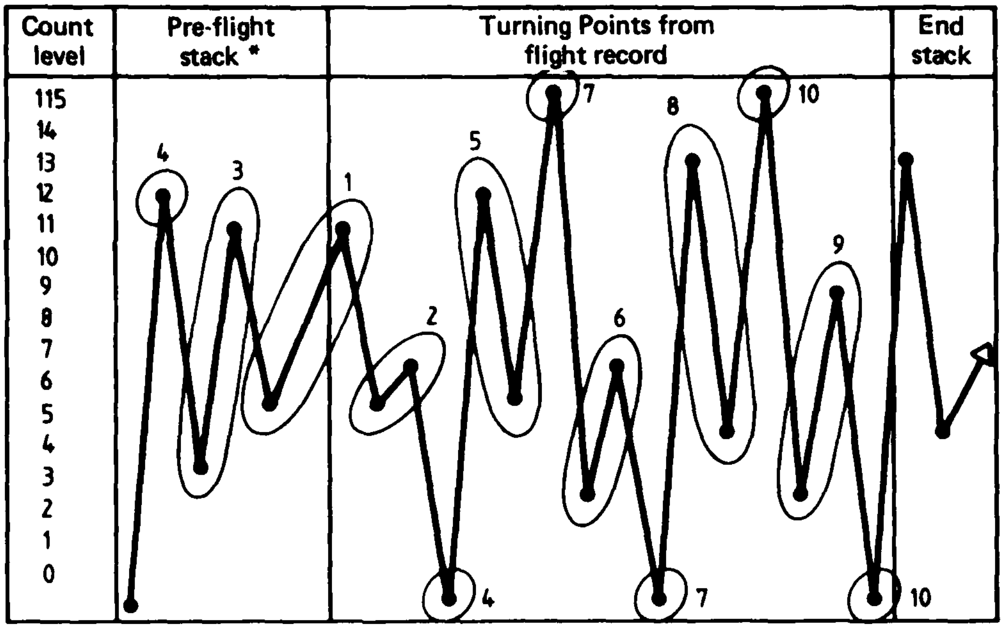


FIG 6 TIME HISTORIES OF STRAIN

Flight 44, Channel 0 Gauge 21C
transition strains from Table 1 Col B.



(a) — Turning point sequence

1	2	3	4	5	6	7	8	9	10

Levels → (6,11), (6,7), (4,11), (0,12), (6,12), (3,7), (0,15), (5,13), (3,9), (0,15)

(b) — Range — mean — pairs, in order of counting.

* Pre flight stack depends on past flying,
not available from AFTRAS records, and
is taken from AFDAS.

FIG 7 METHOD OF COUNTING RANGE MEAN PAIRS FROM AFTRAS RECORD.

AFDAS output for Flight 30 Channel 1

Stack*

Flight	29	30
	1	
	1	
	–	–
	1	
		0/1
	1	1/0
	1	

* +, - =
Termination level and sign

A/B

A=AFDAS
B=AFTRAS

Lower level

Upper level 0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5														
6														
7														
8				1/1										
9														
10														
11	3/2	0/1												
12			1/1											
13														
14	1/1													
15														

FIG 8(a) COMPARISON OF RANGE–MEAN–PAIR COUNTS GAUGE 18T

AFDAS output for Flight 44 Channel 1

Flight	Stack* 43	Stack* 44
	1	1
	1	1
	+	-
		1/1
	1	1
	1	1

* +, - = Termination level and sign

A/B

A=AFDAS
B=AFTRAS

Lower level

Upper level	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5														
6														
7						0/1								
8						2/2								
9					1/0	0/1								
10				2/0	0/2									
11														
12														
13														
14														
15														

FIG 8(b) AS 8(a) FOR GAUGE 18T

AFDAS output for Flight 50 Channel 1

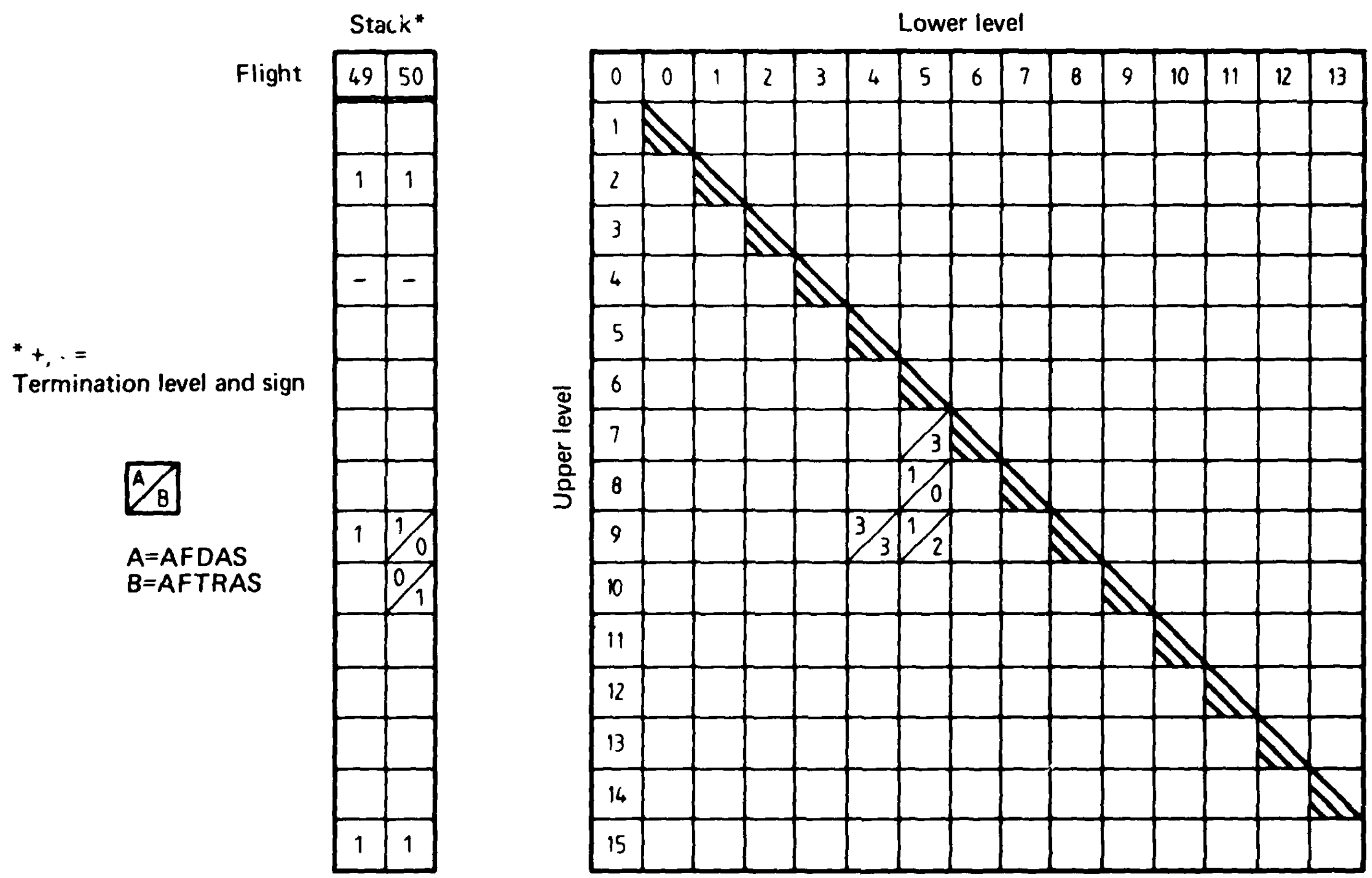


FIG 8(c) AS 8(a) FOR GAUGE 18T

AFDAS output for Flight 44 Channel 0

Stack*

Flight	43	44
	1	
		1/1
	1	
	+	+
	1	
	1	
		1/1

* +, - = Termination level and sign

A/B

A=AFDAS
B=AFTRAS

Lower level

Upper level

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5														
6														
7				1/1		1/0								
8														
9			1/0	0/1										
10														
11					1/1		2/1							
12	1/1						0/1							
13						1/1								
14														
15	2/2													

FIG 8(d) AS 8(a) FOR GAUGE 21T

AFDAS output for Flight 50 Channel 0

Stack*

Flight	49	50
1		
2		
3		
4	1	1/1
5		
6		
7	+	+
8		
9		
10		
11		
12		
13		1/1
14	1	
15		

* +, - = Termination level and sign

A/B: A=AFDAS, B=AFTRAS

Lower level

Upper level	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5		2/0	0/1											
6		0/1												
7														
8							4/2							
9														
10														
11														
12					1/1	1/0	0/1							
13						1/0	0/1							
14	1/1													
15	2/2													

FIG 8(e) AS 8(a) FOR GAUGE 21T

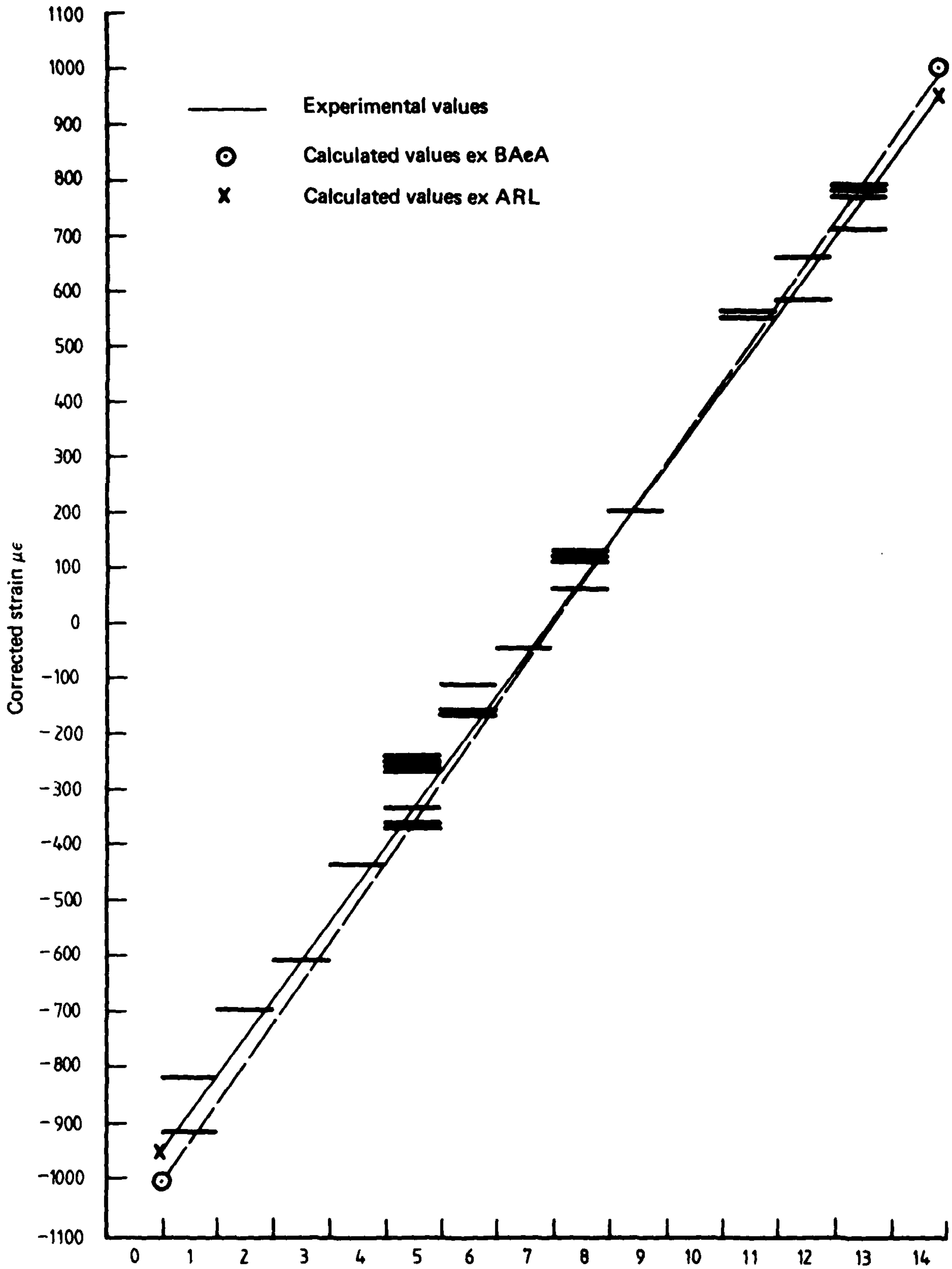


FIG 9 AFDAS LEVEL FOR GAUGE 21C vs CORRECTED STRAIN FROM AFTRAS RECORD FOR GAUGE 21T

AFDAS output for Flights 44 & 50 Channel 0 Gauge 21C

Stack*

Flight	

* +, - =
Termination level and sign

A/B

A=AFDAS
B=AFTRAS

Lower level (columns) / Upper level (rows)

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5		2/2												
6														
7				1/1		1/1								
8							4/4							
9			1/1											
10														
11					1/1	0/1	2/1							
12	1/1				1/1	1/1								
13						2/2								
14	1/1													
15	4/4													

FIG 10 COMPARISON OF RANGE–MEAN PAIR COUNTS

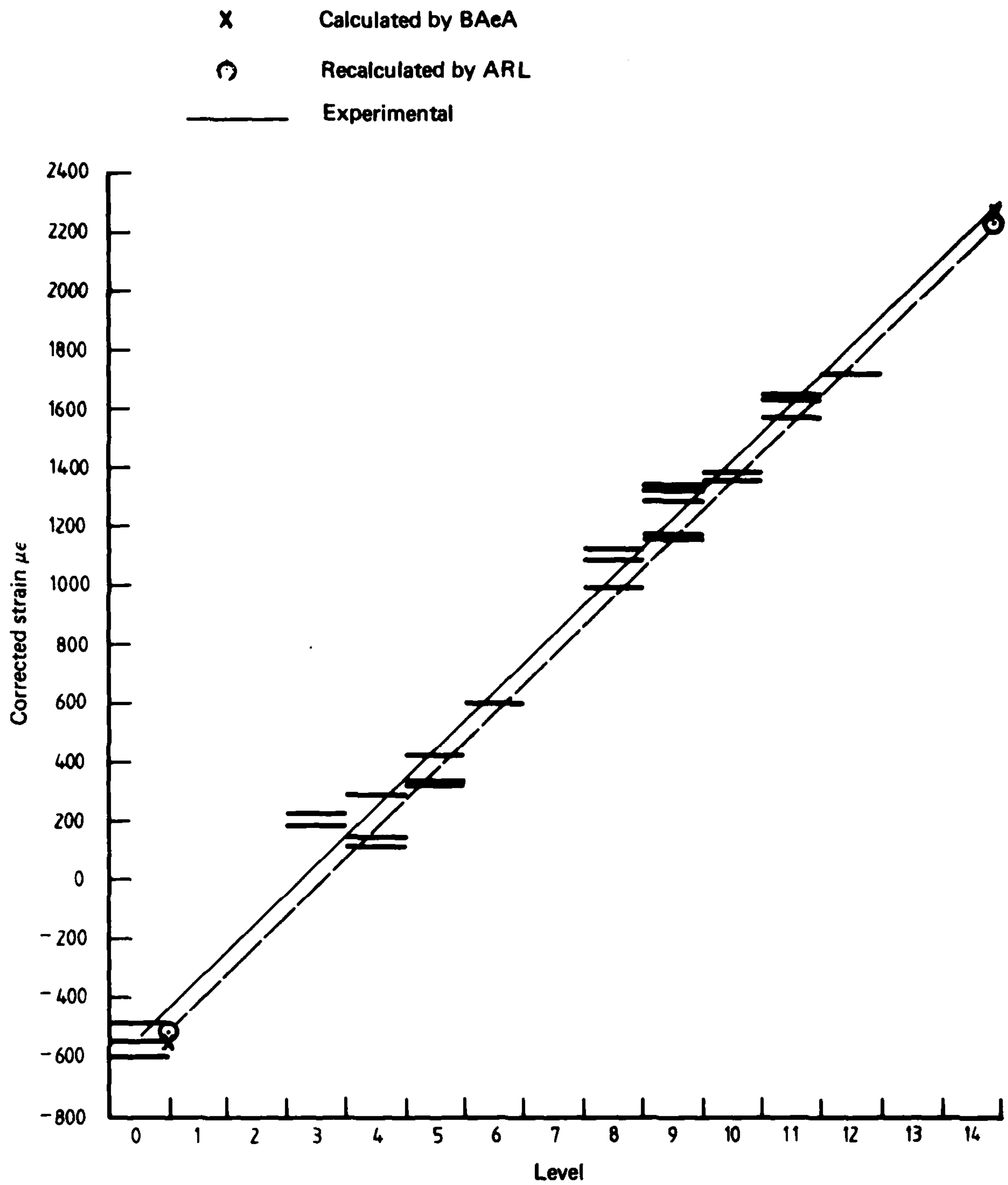


FIG 11 AFDAS LEVEL FOR GAUGE 18T vs CORRECTED STRAIN FROM AFTRAS RECORD FOR GAUGE 1.4T

AFDAS output for Flights 30, 44 & 50 Channel 1, Gauge 18T

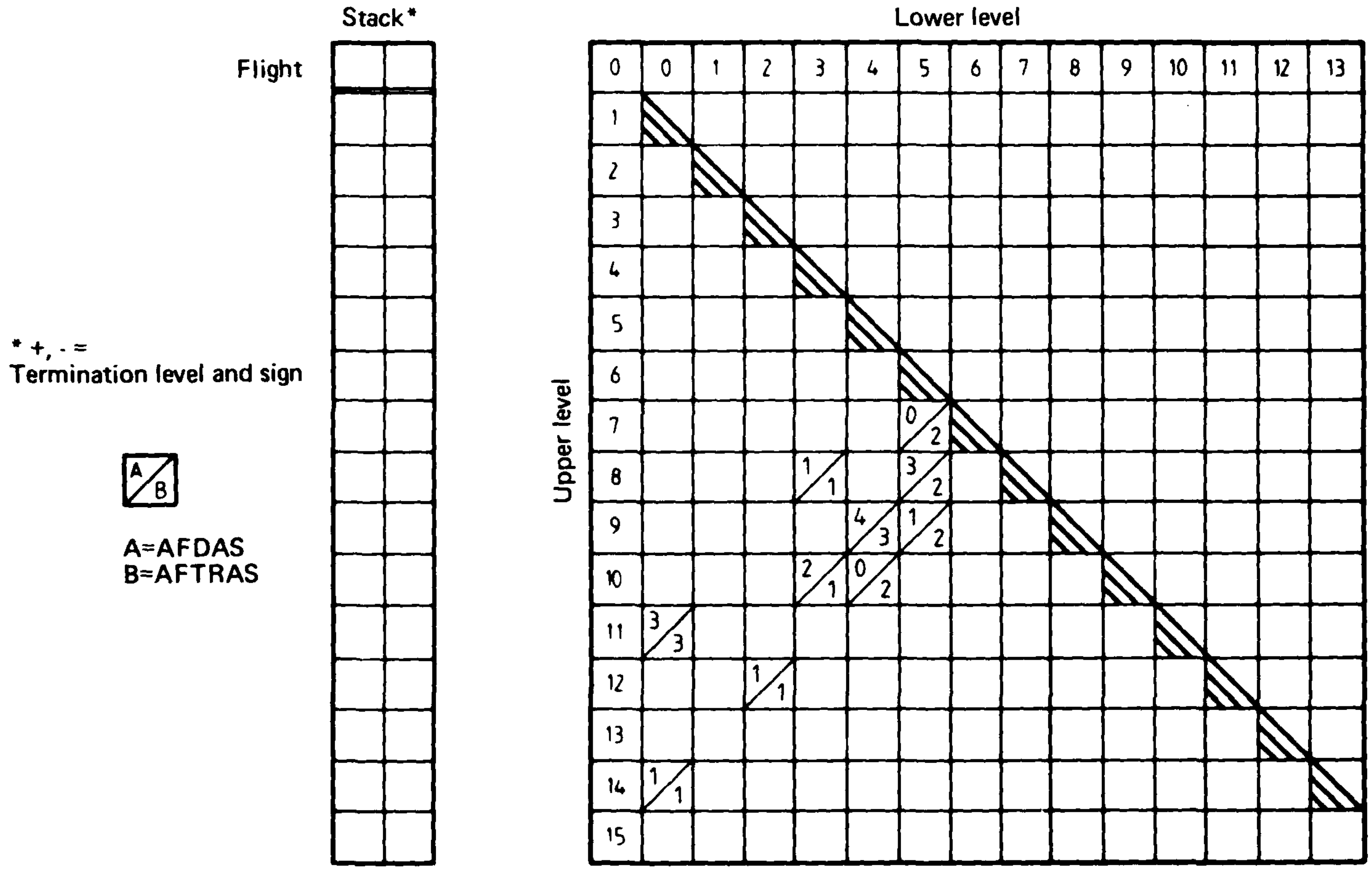


FIG 12 COMPARISON OF RANGE–MEAN PAIR COUNTS

AFDAS output for all Flights Channels 0, 2

Stack*

Flight		

* +, - =
Termination level and sign

A/B

A channel 0
B channel 2
Where different

Lower level (columns) / Upper level (rows)

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5		2												
6			1											
7				1		1								
8						2	141/142							
9			2		1	4	14	19/20						
10														
11					1		2							
12	1				1	1								
13					1	4								
14	1													
15	2													

FIG 13(a) COMPARISON OF RANGE–MEAN PAIR COUNTS

AFDAS output for all Flights Channels 1, 3, 4

Stack*

Flight

*+, - =
Termination level and sign

A/B

A=channel 1
B=channel 3(*)
=channel 4(†)
where different

Lower level

Upper level

0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1														
2														
3														
4														
5			1	13/*12										
6			7/+6	12/+13	32/*33									
7			7	3	37/*36	17/*18								
8				8	20	9	5							
9			1	5	21	4	1	1						
10					8	9	1		5					
11	3		1	1	3	1		1		3				
12			2	4		1				1	3			
13				1	1		1							
14	2												1	
15					1									

FIG 13(b) AS 13(a)

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